

### NOTES RELATING TO THE FLORA OF BHUTAN: III

#### *Pinus bhutanica*: a new 5-needle pine from Bhutan and India

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ABSTRACT. A new species of five-needle pine, *Pinus bhutanica* Grierson, Long & Page (Pinaceae), related to *P. wallichiana* A.B. Jacks. and *P. armandii* Franch., is described from Eastern Bhutan and neighbouring Arunachal Pradesh State, India. Its differences from the other five-needle pines of the Sino-Himalayan region are considered and a discussion of anatomy, distribution and ecology is given.

#### INTRODUCTION

In a preliminary revision of the gymnosperms of Bhutan and Sikkim, in preparation for the Flora of Bhutan, it was recognised that two common *Pinus* species occurred in the area, *P. roxburghii* Sarg. and *P. wallichiana* A.B. Jacks. (*P. excelsa* D. Don nom. illeg., *P. griffithii* McClelland nom. illeg.), and also that several specimens previously referred to the latter species differed from it in their longer, paler, more pendulous foliage and minutely pubescent young shoots. Further investigation revealed that R. E. Cooper during his visit to eastern Bhutan in 1915 had noticed these atypical trees in two districts, and had photographed them and made some descriptive notes which are deposited at the Royal Botanic Garden, Edinburgh. Some years later he commented briefly on these plants when writing about his travels in Bhutan (Cooper, 1933, pp. 83, 85), noting 'It has a pyramidal form, being thickly clothed to the ground with sinuous, long-needled branches', and in his manuscript notes again refers to it as a 'pyramidal, sinuous branched, pendulous, heavy feathered pine'.

Ludlow and Sherriff, who visited the same parts of eastern Bhutan in 1934, 1938 and 1949, also collected specimens of this 'atypical' pine around Tashiyangsi; these were likewise determined as a form of *P. wallichiana*. The first botanist to visit these parts of eastern Bhutan was Griffith, many years previously, in 1838 (Long, 1979), and according to his posthumous publications (Griffith, 1847, p. 211; 1848, p. 123; 1854a, p. 18) he collected a pine at Khegumpa, E Bhutan on 25 i 1838, which he described as having long pendulous needles, silvery glaucous beneath. His field sketch of this plant was later published under the name *Pinus excelsa* D. Don (Griffith, 1854b). His description and illustration suggest very strongly that Griffith was the first person to observe and collect this atypical pine. Unfortunately, no specimen of Griffith's has been located, presumably because the Khegumpa specimens were combined at Kew with collections from western Bhutan, under the name *P. excelsa*, and distributed under one Kew Distribution number: 4991. The two sheets retained in the Kew herbarium bearing this number are typical *P. wallichiana*, almost certainly collected in W Bhutan. Nevertheless, Griffith's collections from Khegumpa probably survive in other herbaria.



FIG. 1. *Pinus bhutanica*: a, photo-silhouette of foliage showing long needles and pendulous habit (Grierson & Long 1986); b, mature cone in open condition; c, seed showing distinctive wing (b & c both G. & L. 2686). a & b  $\times 0.4$ , c  $\times 0.8$ .

In 1979, two of the authors (A.J.C.G. and D.G.L.) resolved to investigate this matter in the field during an expedition to Bhutan, on which it was hoped to visit some of the relevant localities. *Pinus wallichiana* was found to be a common plant in broad dry valleys especially around Thimphu and Bumtang. On reaching Mongar in eastern Bhutan a very strikingly different pine (Grierson & Long 1986) was encountered for the first time. Close examination suggested it was indeed the plant previously collected by Cooper and Ludlow & Sherriff. Subsequent travel in eastern Bhutan enabled us to see the plant in two other districts, to collect more ample specimens of both vegetative parts and cones, to photograph the trees, and to make notes on the plant's appearance and ecology. On returning westwards through Bhutan the plant was seen again unexpectedly, this time in close proximity to typical *P. wallichiana*, enabling the two plants to be photographed together (Plate 1).

Independently, in April 1977, Shri K. C. Sahni of the Forest Research Institute, Dehra Dun, India, recognised a pine at Tenga in the neighbouring Arunachal Pradesh State of NE India (formerly NEFA) with long needles but winged seeds and cones like those of *P. wallichiana*, the identity of which he rightly questioned, noting also its differences in needle anatomy from *P. wallichiana*. He sent this specimen (Sahni & Naithani Ser. II, 381, E) to one of us (C.N.P.) for further study and comparison with known Chinese five-needle pines.

The recent opportunity to compare all the material of this taxon in Edinburgh together with a wide range of specimens of *Pinus wallichiana* and representatives of the other five-needle pines of China, SE Tibet and other parts of SE Asia, has helped to clarify affinities and differences. The Bhutan/NEFA pine seems to have almost equal affinities with the *P. armandii* group (which it resembles mainly in vegetative structure) and with *P. wallichiana* (where the similarities are in the reproductive features), whilst differing in foliage characters from both. It differs substantially from other known Sino-Himalayan and eastern Asiatic pines and thus appears sufficiently distinct in morphology (especially so in the field) to be described as a well-defined independent species. From its known predominant geographic occurrence, we have named it *P. bhutanica*.

#### DESCRIPTION

***Pinus bhutanica*** Grierson, Long & Page species nova. Plate 1, 2; Fig. 1, 2 & 4.

*P. wallichiana* A.B. Jacks. et *P. armandii* Franch. similis ab ambobus foliis plerumque longioribus, e basibus pendulis et ductis resinosis ventralibus asymmetricis recedit.

Arbor circiter 25 m alta vel major, ramulis vernis glaucis, primo brunneis glandulis puberulis. Folia 5 in fasciculo, 15–24 cm longa, serrulata, tenuissima, e basibus pendula; stomata dorsalia nulla, stomata ventralia 4–7 seriebus utrinque; hypodermis 1–3 seriebus cellularum, uniformis; ducti resinosi dorsales 2 marginales ei ventrales 1–2 asymmetrici, marginales vel submarginales; endodermis cum septis exterioribus cellularum tenuibus; fasciculus vascularis singularis, in sectio transversali diameter dimidio circiter folio latitudine aequans; vaginae 2·2–3 cm

longae, deciduae. Strobili subterminales 1–2, 12–20 cm longi, clausi 3–4 cm lati, aperti 5–7 cm lati ovoidei vel ellipsoidei, plus minusve symmetrici, pedunculis 1–6 cm longis; apophyses 1–1.5 cm longae, 1.5–2.5 cm latae, rhombicae, coriaceae, carinatae, ad apices subacutae, brunneae. Semen obovoideum, 7–8 × 4–5 mm, compressum, brunneum, ala persistenti, 20 × 7–10 mm.

BHUTAN: 4 km N of Tschilingor, N of Samdrup Jongkhar, 27°04' N, 91°25' E, 2400 m, 26 vi 1979, *Grierson & Long* 2282 (holotype E; isotype Thimphu, A, BM, K, DD, TI); hillside below Mongar, 27°16' N, 91°12' E, 1750 m, 16 vi 1979, *G. & L.* 1986 (E); Tinlegang, W of Wangdu Phodrang, 27°30' N, 89°48' E, 2020 m, 17 vii 1979, *G. & L.* 2686 (E); Tashiyangsi, Kurted, 27°34' N, 91°28' E, 1830 m, 14 viii 1915, *Cooper* 4457 (E); Sana, Trashiyangsi, 27°35' N, 91°23' E, 2440 m, 7 x 1934, *Ludlow & Sherriff* 1000 (E); Chungkar, 27°03' N, 91°27' E, 1980 m, 12 xi 1938, *Ludlow, Sherriff & Taylor* 7254 (E); Trashy Yangsi Dzong, 27°34' N, 91°28' E, 1675 m, 28 vi 1949, *Ludlow & Sherriff* 20558 (E, BM).

INDIA. Arunachal Pradesh, Tenga Valley, 6 iv 1977, *Sahni & Naithani* Ser. II, 381 (E).

#### DISCUSSION

The distinctive features of *Pinus bhutanica* and of its closest Asiatic relatives, *P. wallichiana* A.B. Jacks., and *P. armandii* Franch. are listed in Table 1, and their distributions are mapped in Fig. 3 and 4. The most important diagnostic features of *P. bhutanica* in herbarium specimens are the very long glaucous-green needles which are pendulous from the base (Plate 1, Fig. 1a), the thin olive-grey bark of the young shoots, the presence of one (rarely two) marginal and asymmetrically placed ventral resin canals in the leaf (Fig. 2), the thin woody cone scales with a median ridge, and the winged seed (Fig. 1b, c).

The overall appearance of the shoot shows interesting contrasts with both *P. wallichiana* and *P. armandii* (Fig. 1a). On leading shoots the needles are spreading at the base, thence arching and descending for the greater part of their length. Those on lateral shoots are all steeply downswept and pendulous; needles arising from the upper side of the shoot all curve from the base but lack the distinctive sudden 'kink' of those of *P. armandii*. The needles appear crowded at the tips of branches, and are mostly shed during their second year, giving, even in young trees, the appearance of densely tufted long pendulous foliage crowded at the branch tips. The needles themselves are 12–28 cm long (much longer than those of either *P. wallichiana* or *P. armandii*), and each has a bright grass-green coloured outer face and two densely glaucous-bloomed inner stomatal faces, giving the tree a predominantly bluish bloomed appearance, more strongly developed than in either *P. wallichiana* or *P. armandii*.

The fascicle sheaths of the needles are also particularly long (mostly 1.8–2.3 cm) and chaffy, bright golden brown in colour; they are retained throughout the first season and conspicuously displayed along the upper sides of the branches by the downswept habit of the needles. These sheaths seem most similar to those of *P. armandii*, but the more pendulous habit of the needles displays them to even greater effect.



PLATE 1. *Pinus wallichiana* (left) growing with *P. bhutanica* (right) at Tinlegang, W Bhutan, June 1979 (Grierson & Long 2687 & 2686 respectively).



PLATE 2. *Pinus bhutanica*: above, fresh specimen showing foliage, immature and mature cones at Tinlegang, W Bhutan, June 1979 (Grierson & Long 2686). Below, mature trees growing in mixed broad-leaved forest near Khaling, E Bhutan, June 1979.



TABLE 1

	<i>P. bhutanica</i>	<i>P. wallichiana</i>	<i>P. armandii</i>
Mature crown habit	Moderately open, not twiggy	Fairly dense, twiggy	Moderately open, not twiggy
Branches	Sinuuous, spreading drooping	Straight, ascending or spreading	Straight, ascending or spreading
First-year shoot	Conspicuously bluish white bloomed. Glandular pubescent	Greenish or weakly whitish bloomed. Glabrous	Often lightly whitish bloomed. Usually minutely glandular pubescent
Second-year shoot	Bark thin, smooth, pale grey-green, wrinkling when dry	Bark $\pm$ thick, grey-brown often $\pm$ scaly, rarely smooth	Bark thin, pale grey-green, wrinkling when dry. Bloom disappearing
Needle length	Mostly 12–28 cm	Mostly 11–18 cm	Mostly 8–18 cm
Needle colour	Outer face grass-green, inner faces strongly whitish bloomed	Medium or dark green, sometimes whitish bloomed on inner faces	Bright grass green, inner faces green or whitish
Needle posture	Pendulous from base even when young. Not kinked	Evenly spreading around shoots, especially when young. Sometimes becoming $\pm$ pendulous. Not kinked	Spreading when young, later spreading at base pendulous from above base, often kinked
Needle persistence	Mostly shed during second year	Persisting until third year	Mostly shed during second year
Needle resin canals, dorsal	2, marginal or submarginal	2, marginal	2, marginal, sub-marginal, or median
Needle resin canals, ventral	1(–2), marginal or submarginal, asymmetric	(0–)1, median, symmetric	1, median, symmetric
Stele diam. in needle t.s.	$\frac{1}{3}$ – $\frac{1}{2}$ breadth of needle	c. $\frac{1}{3}$ breadth of needle	c. $\frac{1}{3}$ breadth of needle
Cone shape	Elongate-cylindric	Elongate-cylindric	Ovoid, becoming barrel-shaped
Cone peduncle length	4.5–6 cm	3–6 cm	2–3 cm
Cone scale woodiness	Thinly woody, $\pm$ flexible, apex flat	Thinly woody, $\pm$ flexible, apex flat	Thickly woody, rigid, $\pm$ reflexed at apex
Seed length	6–8 mm, wing c. 2 cm	6–10 mm, wing 1.5–3 cm	9–19 mm, wing rudimentary 0–2 mm

Although showing some variation, the needle sections from the mid-leaf of *P. bhutanica* with 2 marginal or submarginal dorsal resin canals and 1(–2) marginal or submarginal, always asymmetrically placed, ventral canals, are quite distinct from those of either *P. armandii* or *P. wallichiana* (Fig. 2).

In fresh specimens of *P. bhutanica*, the bluish white bloom of the first-year shoots is a particularly conspicuous character, but the bloom fades on shoots by their second year and becomes readily reduced to a patchy bloom in herbarium material. The fine short pubescence of first-year shoots is densest on weaker shoots and more sparse on stronger ones, and it too becomes lost by the second year, when the characteristically thin developing bark assumes a pale greenish-grey colour. This second-year bark wrinkles lengthwise in herbarium material. These shoot characters of *P. bhutanica* are all shared closely with *P. armandii*.

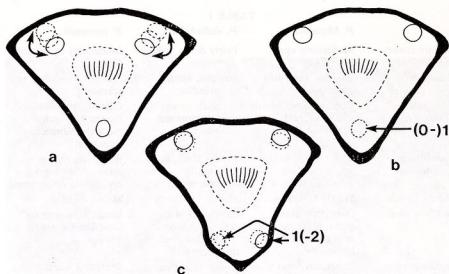


FIG. 2. Diagrams of mid-needle t.s.: a, *P. armandii* with dorsal resin canals varying from marginal to median in different specimens, but with ventral canal always single, symmetrically placed and median; b, *P. wallichiana* with marginal dorsal resin canals and a single median, symmetrically placed ventral canal which is rarely absent; c, *P. bhutanica* with marginal or submarginal dorsal resin canals and one (rarely two) ventral canal which is marginal or submarginal and always asymmetrically placed.

In seed type and in female cone (Plate 2, Fig. 1b, c), however, *P. bhutanica* differs totally from *P. armandii*, and is much more similar to *P. wallichiana*. The cone scales have little of the woodiness of *P. armandii* and the cone lacks the broad, barrel shape of that species. Instead, as in *P. wallichiana*, the scales are lightly structured, more elongate in shape and slightly curved, although each appears to have a more definite longitudinal ridge. The seed, too, is of the small, long-winged type, like *P. wallichiana*, and differs totally from the large, almost unwinged, seed of *P. armandii*.

The tree habit of *P. bhutanica*, when seen growing alongside *P. wallichiana*, however, provides a particularly vivid contrast between these two species, and this contrast is apparent even between young sapling specimens (Plate 1). Trees of *P. bhutanica* have very characteristically long, thin, whip-like, sinuous branches, which are themselves branched only very infrequently, giving both young and old trees a distinctive habit similar to that of *P. armandii*—a habit lacking the many small, twiggy dead interior branches of *P. wallichiana*.

*P. bhutanica* thus shares some features with *P. wallichiana* and some with *P. armandii*, but has a leaf length, leaf habit and range of leaf anatomy distinctive from both. Seed collected in Bhutan has proved fertile, and has germinated successfully at Edinburgh. Because of its fertility and distinctive morphological features we do not believe it to be of recent hybrid origin between *P. wallichiana* and *P. armandii*, but more likely a relict species containing some of the attributes of both these species, combined with others that have evolved independently. In this it compares closely with the situation discussed recently for *Picea farreri* in Burma (Page & Rushforth, 1980).



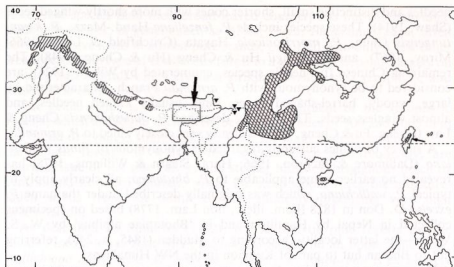


FIG. 3. Distribution, excluding Bhutan, of *Pinus wallichiana* (single-hatched) and *P. armandii* (cross-hatched) after Critchfield & Little (1966) including related specimens of doubtful identity ▴. For detailed distribution of 5-needle pines in Bhutan and adjacent areas see Fig. 4.

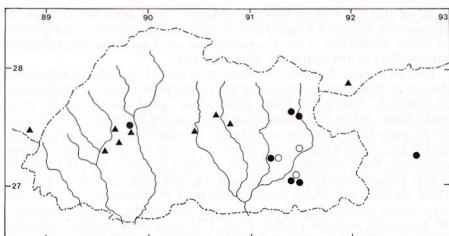


FIG. 4. Distribution of 5-needle pines in Bhutan and adjacent areas: ▲ *Pinus wallichiana* and ● ○ *P. bhutanica* (● herbarium specimens; ○ personal observations and literature records).

The only other SE Asian five-needle pine to which *P. bhutanica* appears to be closely related is *P. dalatensis* Ferré, from Vietnam (Ferré, 1960; Mirov, 1967), which, from illustrations, appears to have cones and seeds similar to those of *P. bhutanica* and *P. wallichiana*. It differs clearly from *P. bhutanica*, however, in having much shorter leaves (4–10 cm), and in the complete absence of a ventral resin canal.

Amongst the other five-needle pines described from the Chinese region most are synonymous with, or closely related to, *P. parviflora* Sieb. & Zucc.; they differ from *P. wallichiana* and its allies in their much shorter

needles and distinctive small, shorter cones with more shortly-winged seeds (Shaw, 1914). These species include *P. fenzeliana* Hand.-Mazz., *P. kwan-tungensis* Chun, *P. morrisonicola* Hayata (Critchfield & Little, 1966; Mirov, 1967), and *P. wangii* Hu & Cheng (Hu & Cheng, 1948). The remaining Chinese five-needle species, enumerated by Wilson (1926), are considered to be synonymous with *P. armandii* Franch., characterised by large, woody, barrel-shaped cones, long, usually kinked needles, and almost wingless seeds. The recently described *P. dabeshanensis* Cheng & Law (Cheng, Fu & Cheng, 1975) is clearly very closely allied to *P. armandii*.

A survey of names currently regarded as synonymous of *Pinus wallichiana* (Dallimore & Jackson, 1966; Hara, Stearn & Williams, 1978) has revealed no earlier name applicable to *P. bhutanica*; all clearly apply to typical *P. wallichiana*, which was originally described under the name *P. excelsa* D. Don in 1828 (hom. illeg., non Lam. 1778) based on specimens collected in Nepal by Hamilton and in 'Bhotaniae alpinus' by W. S. Webb—the latter locality, according to Madden (1845, p. 245), referring not to Bhutan but to part of Kumaon in the NW Himalayas.

No specimens resembling *P. bhutanica* have been traced from Sikkim or parts of the Himalayas farther west, nor has mention of such plants apparently been made in the literature, either in Bhutan or elsewhere (cf. Banerji, 1952; Raizada & Sahni, 1960; Maheshwari & Konar, 1971; Shrestha, 1974).

In all the localities in which *P. bhutanica* was observed in 1979 the populations displayed a high degree of uniformity, and even when growing in close association with *P. wallichiana* at Tinlegang, no specimens intermediate in any characters were observed.

East of Bhutan, however, the situation is much less clear-cut and a good deal more field work is required in SE Tibet and W China to sample *Pinus* populations. Specimens from these areas, some closely allied to *P. wallichiana*, others combining some characters of *P. bhutanica* with some of *P. wallichiana*, do exist in herbaria. Previous authors, e.g. Wu (1956) and Wang (1961) have referred some of these to the latter species without comment. Three specimens: Ludlow, Sherriff & Taylor 3711 (E) from SE Tibet, Handel-Mazzetti 1768 (E), and Yu 19591 (E), both from Yunnan, show the long pale bluish pendent foliage of *P. bhutanica*; the latter two have young shoots with a glaucous bloom, but lack the shoot pubescence of *P. bhutanica*, whereas Ludlow *et al.* 3711 does show strongly pubescent shoots as in *P. bhutanica*. Of these three specimens, only Handel-Mazzetti 1768 shows the characteristic needle anatomy of *P. bhutanica*, the others show that of *P. wallichiana*. Another specimen, Ward 1684 (E) from Upper Burma, is closer to typical *P. wallichiana* both morphologically and anatomically. Clearly until better collections and information from these areas are available, these specimens cannot be reliably equated with *P. bhutanica*, *P. wallichiana* or any other species known at present. Some may indeed be of hybrid origin, but a few, notably Yu 19591 and Handel-Mazzetti 1768, approach *P. bhutanica* very closely.

#### ECOLOGY AND DISTRIBUTION OF PINES IN BHUTAN

In Bhutan, as in other regions of the Himalayas, coniferous forests are a very conspicuous and important vegetational feature. They contain far

fewer tree species than their broad-leaved counterparts but the individual dominant species, in genera such as *Abies*, *Picea*, *Pinus* and *Tsuga*, often cover extensive areas in almost pure stands, or mixed with only a few other tree species. The type of coniferous forest in a given area depends largely on altitude and rainfall which create a striking division into xerophytic and mesophytic coniferous forests.

The genus *Pinus* is the only coniferous constituent of the xerophytic forests, which are found exclusively between altitudes of 900 and 3000 m in the broad dry valleys running south from the main Himalayan chain. The mesophytic forests, in which *Pinus* occurs much less frequently, are characteristic of the side valleys and steeper hillsides throughout much of central and northern Bhutan, where the steep slopes force the moisture-laden winds from the south to rise suddenly producing very high precipitation.

As described by Stainton (1972), the xerophytic pine forests can be divided into a lower zone of *P. roxburghii* Sarg. and an upper zone of *P. wallichiana* A.B. Jacks. (*P. excelsa* D. Don). *P. roxburghii* is exclusively xerophytic and appears never to occur in moister side valleys, unlike *P. wallichiana* which, although forming pure stands only in the main dry valleys, can occur in wetter side valleys, but then never as a dominant and only in association with other tree species such as *Quercus* and *Picea*. *Pinus bhutanica* differs from both these pines in its apparent preference for moister forest: nowhere has it been seen in the main dry valleys or even forming pure stands; in all its observed localities it is mixed with broad-leaved species such as *Quercus* and *Lithocarpus*.

#### 1. *Pinus roxburghii*

In Bhutan the forests of this species (the 'chir pine') are very similar to those described in Nepal by Stainton (1972), although the association he described in some Nepalese localities with *Shorea robusta* Gaertn. is unknown in Bhutan. The forest occurs in the lower valleys between 900 and 2000 m where the pines form almost pure stands of trees up to 30 m tall, with relatively few associated tree or shrub species due to the frequency of fires, which are encouraged to improve grazing but to which mature pines are resistant.

In some places a few other small tree species may be associated, e.g. *Cycas pectinata* Ham., *Euphorbia royleana* Boiss., *Ficus oligodon* Miq., *Punica granatum* L., *Rhus paniculata* Hook. f., and *Zizyphus incurva* Roxb. Associated shrubs are more frequent, especially by rivers and in more sheltered spots, examples being *Buddleja asiatica* Lour., *B. bhutanica* Yamazaki, *Grewia sapida* DC., *Indigofera dosua* D. Don, *Osyris lanceolata* Hochst. & Steud., *Securinega suffruticosa* (Pall.) Rehd., *Solanum erianthum* D. Don and *Woodfordia fruticosa* (L.) Kurz. Numerous herbs occur, many of them appearing only during the monsoon season, but a few species, such as the lemon-grass, *Cymbopogon flexuosus* (Steud.) Wats., provide more extensive ground-cover.

In Bhutan this type of forest was seen in 1979 in the main valleys of the Mo Chu-Sankosh River (Punakha, Wangdu Phodrang districts), Mangde Chu valley (Shamgong district), Kuru Chu valley (Mongar district) and Kulong Chu-Dangme Chu valleys (Tashigang district). In all of these

valleys the upper limit of *Pinus roxburghii* was rather sharply defined at between 1700 and 2000 m.

## 2. *Pinus wallichiana*

The 'blue pine' or 'kail' is an important timber tree in Bhutan, very abundant in the inner dry valleys between 2300 and 2900 m, where it often forms extensive pure stands. Stainton (1972) reported that in Nepal it frequently behaved as a colonist of disturbed or previously cultivated areas where its high regeneration capacity allowed it to spread quickly. This is undoubtedly true in some parts of Bhutan, but areas of probably undisturbed ancient forest also exist. Around Thimphu much replanting has been undertaken in recent years to replace both the many mature trees felled during the reconstruction of Thimphu Dzong and those areas of forest destroyed by fire, to which, unlike *P. roxburghii*, this species is very susceptible.

In the pure stands of the inner dry valleys no other tree species occur, apart from *Quercus griffithii* Miq. in more sheltered localities. Shrubs, however, are frequent, typical being *Berberis asiatica* DC., *Ceratostigma griffithii* Clarke, *Cotoneaster griffithii* Klotz, *Elaeagnus parvifolia* Royle, *Euonymus grandiflorus* Wall., *Leptodermis scabrida* Hook. f., *Lonicera quinquelocularis* Hardw., *Prinsepia utilis* Royle, *Quercus semecarpifolia* Sm., *Rhododendron arboreum* Sm. and *Zanthoxylum armatum* DC. Herbs are likewise well-represented, many of them appearing during the monsoon season, such as *Arisaema consanguineum* Schott, *Ophiopogon intermedius* D. Don, *Phtheirospermum tenuisectum* Bur. & Franch., *Polygala sibirica* L., *Polypogon fugax* Steud., *Potentilla griffithii* Hook. f., and *Vincetoxicum album* (Mill.) Aschers. A mossy turf commonly occurs as a ground layer in which species of *Hypnum* and *Rhytidium rugosum* (Hedw.) Kindb. are abundant. Such pure forests are best represented in Bhutan in the Ha, Paro and Thimphu valleys in the west and in mid Bhutan in the Bumtang and Gyetsa valleys (Fig. 4). The distribution in NE Bhutan, where its range overlaps with that of *P. bhutanica*, is uncertain, but Cooper 4458 from Tashi Yangsi and Ludlow & Sherriff 6421 from neighbouring SE Tibet are almost indistinguishable from *P. wallichiana*, but the extent of its occurrence in both these areas is unknown.

*Pinus wallichiana* also occurs in more mesophytic forest communities which represent to some extent a transition between the xerophytic forest and the very wet *Picea*, *Tsuga* and *Abies* forests. Such mesophytic forest occurs in side valleys around the Thimphu and Bumtang valleys in small quantity, but more extensively in the Longte Chu valley around Chendebe and in the Ura district. The altitudinal range of such habitats is between 2600 and 3300 m. The pines in these areas are often large healthy trees scattered throughout forest in which other trees include *Acer* species (e.g. *A. campbellii* Hiern, *A. hookeri* Miq., and *A. pectinatum* Pax), *Larix griffithiana* Carr., *Malus baccata* (L.) Borkh., *Picea spinulosa* (Griff.) Henry and *Prunus cornuta* (Royle) Steud. The pines support a rich epiphytic flora of bryophytes and lichens and many are hosts to the loranthaceous parasite *Taxillus kaempferi* (DC.) Danser. Undershrubs are conspicuous and dense, e.g. *Arundinaria* and *Berberis* species, *Elaeagnus parvifolia* Royle, *Leycesteria formosa* Wall., *Lindera heterophylla* Meissn.,

*Piptanthus nepalensis* (Hook.) D. Don, *Rosa macrophylla* Lindl. and *R. sericea* Lindl. Similar mixed forest has been reported from parts of Nepal by Stainton (1972). It is possible that occurrence of this intermediate forest can be partly accounted for by a rainfall intermediate between that of the dry valleys and the very wet types of coniferous forest.

### 3. *Pinus bhutanica*

This species is very local in its distribution in Bhutan (Fig. 4); nowhere has it been observed forming pure stands of any extent, which has no doubt contributed to the lack of study of it by previous botanists visiting Bhutan. It is distinctly eastern in distribution, with the exception of the single outlying western locality, and only in the hills around Khaling and Wamrung had it been noted in any quantity and forming large mature trees (Plate 2). The observed altitudinal range is from 1750 to 2400 m, thus partly overlapping the ranges of *P. roxburghii* and *P. wallichiana*.

In its ecology, present knowledge of which is very incomplete, *P. bhutanica* differs from the other two species in that it shows a marked preference for moist mixed broad-leaved forest in eastern Bhutan, although around Khaling (Plate 2) its density is greater on the drier ridges than in the moister valleys between them. The main associates there are trees such as *Quercus*, *Lithocarpus* and *Betula* species, and shrubs including several Lauraceae, *Acer hookeri* Miq., *Neillia rubiflora* D. Don, *Rosa moschata* Herrm., *Piptanthus nepalensis* (Hook.) D. Don, and *Zanthoxylum acanthopodium* DC. In the Mongar area, where the species is uncommon and the trees of low stature, the commonest associates noted are *Quercus griffithii* Miq. and *Q. lanata* Sm., indicating a slightly drier environment. In its outlying western locality at Tinlegang the pine was seen in secondary forest, again with *Quercus lanata* and other broad-leaved species, and also with *Pinus wallichiana*; this is the only locality in which both pines have been seen in close association.

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### REFERENCES

- BANERJI, M. L. (1952). Observations on the distribution of Gymnosperms in Eastern Nepal. *J. Bombay Nat. Hist. Soc.* 51:156-159.  
CHENG, W.-C., FU, L.-K., & CHENG, C.-Y. (1975). Gymnospermae Sinicae. *Acta phytotax. Sin.* 13:56-90  
COOPER, R. E. (1933). Botanical tours in Bhutan, with special reference to the occurrence of the genus *Primula*. *Notes R.B.G. Edinb.* 18:67-118.

- CRITCHFIELD, W. B. & LITTLE, E. L. (1966). Geographic distribution of the pines of the world. *U.S.D.A. Misc. Publ. No. 991*. Washington.
- DALLIMORE, W. & JACKSON, A. B. (1966). *A handbook of Coniferae and Ginkgoaceae*. Revised ed. by S. G. Harrison. London.
- FERRÉ, M. Y. DE (1960). Une nouvelle espèce de pin au Viet-Nam. *Pinus dalatensis*. *Bull. Soc. Hist. Nat. Toulouse*. 95:171-180.
- GRIFFITH, W. (1847). *Journals of travels in Assam, Burma, Bootan, Affghanistan and the neighbouring countries*. Ed. J. McClelland. Calcutta.
- (1848). *Itinerary notes of plants collected in the Khasyah and Bootan mountains, 1837-38, in Affghanistan and neighbouring countries, 1839-41*. Ed. J. McClelland. Calcutta.
- (1854a). *Notulae ad plantas asiaticas*. Part iv. Ed. J. McClelland. Calcutta.
- (1854b). *Icones plantarum asiaticarum*. Vol. 4. Ed. J. McClelland. Calcutta.
- HARA, H., STEARN, W. T. & WILLIAMS, L. H. J. (1978). *An enumeration of the flowering plants of Nepal*. Vol. 1. London.
- HU, H.-H. & CHENG, W.-C. (1948). Some new trees from Yunnan. *Bull. Fan Mem. Inst. Biol.* (n.s.) 1:191-198.
- LONG, D. G. (1979). The Bhutanese Itineraries of William Griffith and R. E. Cooper. *Notes R.B.G. Edinb.* 37:355-368.
- MADDEN, E. (1845). On Himalayan Conifers. *J. Roy. Hort. Soc.* 5:228-269.
- MAHESHWARI, P. & KONAR, R. N. (1971). *Botanical Monograph No. 7. Pinus*. New Delhi.
- MIROV, N. T. (1967). *The Genus Pinus*. New York.
- PAGE, C. N. & RUSHFORTH, K. D. (1980). *Picea farreri*, a new species of temperate conifer from Upper Burma. *Notes R.B.G. Edinb.* 38:129-136.
- RAIZADA, M. B. & SAHNI, K. C. (1960). Living Indian Gymnosperms—Part 1. (Cycadales, Ginkgoales and Coniferales). *Indian For. Res. n.s. Bot.* 5:1-150.
- SHAW, G. R. (1914). *The genus Pinus*. Cambridge, Mass.
- SHRESTHA, T. B. (1974). Gymnosperms of Nepal. *Cahiers nepalais No. 3*. Paris.
- STANTON, J. D. A. (1972). *Forests of Nepal*. London.
- WANG, C.-W. (1961). *The Forests of China*. Maria Moors Cabot Foundation Publ. No. 5. Harvard Univ., Cambridge, Mass.
- WILSON, E. H. (1926). The taxads and conifers of Yunnan. *J. Arn. Arb.* 7:37-48.
- WU, C.-L. (1956). The taxonomic revision and phytogeographical study of Chinese pines. *Acta Phytotax. Sin.* 5:131-164.